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SOUTH AFRICA        SUID-AFRIKA

STANDARD NOMENCLATURE AND METHODS FOR
DESCRIBING THE CONDITION OF PAVEMENTS
(DRAFT TRI 6)

by

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The need for describing the condition of pavements occurs frequently in highway engineering. Accurate descriptions are a prerequisite for establishing procedures with which to evaluate the various aspects of the pavement condition. A variety of methods and terms have been used in practice. Consequently descriptions of pavements are apt to be incomplete and ambiguous. This document is a recommendation of a standard usage for South Africa.

It must be emphasised, however, that this document does not give suggestions for the evaluation of the condition of the pavement or recommend those aspects that should be described in given situations. It is for the engineer to decide in which context a pavement is to be evaluated and thus what descriptions are necessary. The necessary inspection schedule can then be set up in accordance with these recommendations. It is also important to note the cost of inspection when setting up a schedule. Detailed descriptions are costly, especially if long stretches of road are involved. Therefore careful attention must be given to how each aspect will be used in the subsequent evaluation and whether the cost is justified, before the schedule is set up.
1. **INTRODUCTION**

There are two viewpoints from which the condition of a road can be considered. These are the point of view of the road user and that of the road engineer. The road user regards the road as a service provided for transportation and appraises its condition in terms of those characteristics affecting his comfort, safety and convenience. The engineer recognises the functional requirements of a road, but in addition views the road as a structure which must withstand the effects of traffic and other forces. If this is not accomplished the structure will deteriorate and finally be unable to fulfil its functional requirements.

Over past years terms have been brought into use by which the condition of the pavement can be described. It is recognised that clear and unambiguous descriptions are a prerequisite for quantitative assessments of the pavement. However, current terms are not all explicit or used uniformly. Presented herein is a nomenclature for descriptions of pavement condition within the conceptual structure of the evaluation (quantitative assessment) of the condition. Such evaluations are used in the following aspects of road engineering.

(a) The evaluation of the degree of success with which a particular design has met the design criteria and of the cause of failure where the criteria have not been met in order to provide a basis for comparing designs of promoting new designs.

(b) The determination of the type of maintenance required in a specific case and the provision of a basis for establishing maintenance priorities and for comparing maintenance strategies in order to determine the optimum maintenance programme.

(c) The evaluation of the adequacy of the pavement in carrying the required volume and type of traffic in order to provide a basis for sufficiency ratings and needs studies.

(d) Communication between engineers on a technical level, either for transmitting useful observations or for justifying proposed courses of action.
(e) Engineering research, in developing new materials, construction techniques and design methods by means of field trials.

The nature and detail of descriptions of pavement condition will vary according to the purpose. For example, the description may be a comprehensive one over a small area of pavement when describing a particular problem, whereas it would only be practical to give a less detailed description of long lengths of road in condition surveys.

The scope of condition evaluation in terms of the points of view given above is defined more formally in Section 2.

Section 3 discusses in greater detail descriptions of pavement condition from the road user's point of view, whereas Section 4 discusses other engineering aspects of pavement condition where a description of the pavement includes details pertaining to the pavement structure. The use of limiting values of pavement condition is discussed in Section 5. Appendix I gives methods of describing pavement distress in detail. This is the visible manifestation of the deterioration of the pavement. Appendix II gives examples of various schedules for describing pavements with a view to specific purposes. Finally a glossary is provided giving definitions of all terms introduced herein.

2. THE SCOPE OF PAVEMENT CONDITION EVALUATION

The pavement is regarded from the outset in the light of its ultimate function which is to provide a facility for vehicle transportation. This facility must be maintained at a sufficiently high level of service to accommodate the requirements of road user's at the lowest possible cost. Minimum requirements are set according to the funds that can be made available in competition with those needed for other public requirements. The assessment of a given pavement in this light will include a consideration of the level of service provided by the facility and an estimation of any future change in the pavement that will ultimately cause the present level of service of the pavement to deteriorate. This change is brought about by the action of traffic and environmental forces on the pavement structure. If a serious change is foreseen (i.e. one that will prematurely
lead to the pavement not providing the minimum requirements of the road user) then appropriate maintenance measures must be considered which will remedy the deterioration.

The scope of pavement condition evaluation is then:

(a) The assessment of the level of service provided by the facility in relation to the minimum requirements. This is the assessment of the degree to which it fulfils its function and is thus the functional evaluation of the pavement;

(b) The assessment of the capacity of the pavement to withstand the effects of climate and traffic. This is referred to as the structural capacity of the pavement and the process of assessing this is the mechanistic evaluation of the pavement. This definition implies that if the future climatic and traffic conditions can be determined, then these can be used together with a knowledge of the structural capacity to predict future changes in the pavement. Furthermore, if it is known how various maintenance measures will alter the structural capacity of the pavement, appropriate maintenance strategies can be determined which will ensure a given level of service, and the best strategy can then be selected taking economic considerations into account.

The result of a mechanistic and a functional evaluation is to define aspects in which the pavement is deficient and thus to enable appropriate corrective measures to be applied. These corrective measures are defined as the road's needs.

Ready and uniform methods for doing functional and mechanistic evaluations and for predicting future changes in the pavement are not available. Various methods are currently used which are a combination of the use of objective, experimental relationships and subjective judgement based on local experience. The objective of this note is to define various concepts used in such analyses and to enumerate the various factors of pavement condition that may be considered. A standard nomenclature is necessary for developing uniform recording procedures and evaluation methods.
3. **FUNCTIONAL DESCRIPTION OF PAVEMENT CONDITION**

The extent to which a particular road meets its functional requirements which are the speed, safety, comfort and convenience of the road user is defined as the *serviceability* of the pavement. The minimum functional requirement specified for a particular road is termed the *terminal level of serviceability*. During the life of a road the serviceability will change. The trend of the serviceability with time is defined as the *performance* of the road. Figure 1 gives an example of the performance of a hypothetical road in order to illustrate these concepts.

The functional requirements, speed, safety, comfort and convenience are not easily and uniquely measured as such and their respective values would not always be a useful description with respect to serviceability. For instance, it is not sufficient to know that the safety is inadequate - the reason for this is also required. Also, these requirements are interrelated (e.g. safety depends on speed) and the relative influence of the interacting parts is not well known. For these reasons various *features* of the road have been considered which directly affect the provision of the functional requirements. For surfaced roads, these are the geometric properties, the skid-resistance, the surface drainage and the riding quality and (to a lesser extent) environmental factors such as noise generation and the aesthetic appearance of the pavement. The serviceability, terminal value and performance can each be given in terms of one or more features of the road. These features are listed in Table I together with the factors that contribute to the serviceability and current methods of assessment. These features are discussed in the following:

**Riding quality**

The riding quality of a road is defined as the general extent to which road users experience, through the medium of their vehicles, a ride that is smooth and comfortable or bumpy (and thus unpleasant and perhaps unsafe). The value of the riding quality can be obtained by obtaining the average rating (on a scale 0 to 5) by a sufficient sample of road users. A
<table>
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<th>FEATURE</th>
<th>FACTORS CONTRIBUTING TO SERVICEABILITY</th>
<th>METHOD OF ASSESSMENT</th>
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| 1. Geometric properties | (a) amount of camber or crossfall  
(b) road width  
(c) vertical alignment  
(d) horizontal alignment   |                                                          |
| 2. Skid-resistance     | (a) surface texture depth  
(b) harshness of surface  
(c) water film thickness | SCRIM, NIPR brake-force trailer, pendulum apparatus  
see (3) below |
| 3. Surface drainage    | (a) transverse and longitudinal grades  
(b) efficiency of drainage system  
(c) deformation of surface profile, particularly rutting in the wheel paths | levelling, inspection during rain  
inspection during rain  
inspection during and after rain, straight-edge measurements |
| 4. Riding quality      | (a) longitudinal surface roughness (deformation)  
(b) rutting in wheel paths (deformation)  
(c) potholes  
(d) uneven patching | (i) Subjective rating of PSI in a vehicle  
(ii) Measurement of PSI using PCA Roadmeter*, BPR Roughometer*, CHLOE Profilometer*  
straightedge measurements  
regular inspection  
inspection (also included in (i) and (ii) above) |

*Instruments must be calibrated from present serviceability rating (PSR) results obtained subjectively by a panel of raters.
sufficient sample is considered to be one that is representative of the road users and large enough to estimate the mean to a desired degree of accuracy. The value obtained in this way is termed the PSR (present serviceability rating) of the road.

The riding quality of a road is determined by the profile of its surface. Thus it is reasonable to expect that some form of measurement of the profile can be used to estimate the riding quality. The measures that are commonly used are the longitudinal slope variance of the profile together with the average transverse rut depth. The slope variance is defined as the variance of slope of the road measured longitudinally in the outer wheel track at intervals of 150 mm, where the slope at a point on the road is the tangent of the angle the surface of the road makes at that point with a beam 8 m long supported at each end at equal heights above the road surface, one end being the point of measurement (see Figure 2). The slope variance is commonly measured with the CHLOE profilometer shown in Figure 3. The average rut depth is the average maximum deviation measured under a 2 m straight edge placed transversely, across the outer wheel track at random points along the road. A relationship between these parameters and the riding quality was established during the AASHO Road Test, viz:

\[
PSI = 5.03 - 1.91 \log (1 + SV) - 1.38 RD^2 - 0.01 \sqrt{C + P}
\]

where

- \(PSI\) = Present serviceability index which is the measure of riding quality
- \(SV\) = slope variance
- \(RD\) = mean rut depth (in inches)
- \(C\) = 10 times the percentage cracking
- \(P\) = 10 times the percentage patching

The term \(C + P\) was subsequently found not to be significant. An equivalent metric equation is then

\[
PSI = 5.08 - 2.03 (1 + SV) - 0.00212 RD^2.
\]

where

- \(RD\) = mean rut depth in mm
As a vehicle moves over a road with poor riding quality the body of the car will oscillate on its suspension relative to the axles. Use of this phenomenon is made in the provision of high speed instruments for estimating riding quality. In these instruments the relative movement between the axle and the body of a vehicle or the frame of a specially made trailer is recorded, weighted according to its amplitude and summed. These values are correlated with values of PSR in order to calibrate the instruments. Subsequent measurements of riding quality with such calibrated instruments are described as values of PSI for a particular instrument under the particular conditions. Examples of such instruments are:

(a) PCA roadmeter (Figure 4). The movement between the rear axle and the body of a sedan car is recorded and each movement is weighted by the square of its amplitude and summed.

(b) The BPR roughometer (Figure 5). The movement between the axle and frame of a specially designed trailer is recorded and each movement is weighted by its amplitude.

The PCA roadmeter operates at 80 km/h or 50 km/h, the BPR roughometer at 40 km/h and the CHLOE Profilometer at 5 km/h. The PCA roadmeter is the least accurate of these instruments but operates at a speed which does not interfere with traffic and is thus suitable for routine measurements by a road authority. The CHLOE profilometer is the most accurate instrument but is unwieldy and slow and requires special traffic control during operation and is thus only used in the calibration of special control road sections that are used in turn to calibrate the other instruments. The BPR roughometer operates at intermediate levels of accuracy and speed and is normally used for research projects.

The performance of a road in terms of riding quality is the most important parameter by which the efficacy of methods of structural design can be evaluated. The reason is that the ultimate effect of any significant structural deterioration of the pavement is the reduction of riding quality.

Riding quality measurement can be carried out at regular intervals by road authorities in order to detect which roads are approaching or are below the terminal level of riding quality set for that class of road, so that effective remedial measures can be programmed.
Skid-resistance

Skid-resistance is a term used to describe the general ability of the road surface to prevent skidding in all or particular manoeuvres generally executed by vehicles. The definition may be narrowed where required to refer to the ability of the road to allow specified manoeuvres under specified conditions. In this case one may talk, for example, of a road having a high skid-resistance for cornering when wet.

The ability of a particular vehicle to execute a particular manoeuvre depends on the coefficient of friction between each of its tyres and the road surface during the manoeuvre. The coefficient of friction is defined as:

\[
\mu = \frac{F}{N}
\]

where 
- \( F \) = the force developed by the friction between the surfaces and is the force by which the manoeuvre is controlled
- \( N \) = the force normal to the plane of friction due to the weight of the vehicle.

The value \( \mu \) is however not a constant for a particular section of road but depends on several other factors such as the type of tyre, the type of manoeuvre (mainly the speed and acceleration of the wheel) and on whether the surface has been lubricated (with water or oil). Since this coefficient is not unique, the approach has been to develop instruments that can be used to estimate the average coefficient of friction that would apply to vehicles executing certain manoeuvres under wet conditions. These instruments are operated under specified and carefully controlled conditions (these are generally constant speeds and constant rates of wetting the surface of the road with water). The measurements obtained from these instruments are referred to as coefficients of skid-resistance for the stated instrument and test conditions.

Three types of instruments have been used by the NIRR for measuring skid-resistance. They are the brake-force trailer, SCRIM and the pendulum tester. These are described in the following:

(a) **Brake-force trailer.** This is a single-wheel brake-force trailer device, which is shown in Figure 6. It is towed by a light-delivery
vehicle which carries a sufficient supply of water for about 25 tests. At the test speed the smooth-tyred wheel is locked for about 2 seconds over the wetted surface. This short test period is to limit wear on the tyre. The braking force is measured by strain gauges and the relation between the braking force and the normal load on the wheel is called the brake-force coefficient (bfc) and is related to the decelerating performance of a vehicle when its wheels are fully locked.

(b) **SCRIM.** SCRIM is an abbreviation for Sideway-force Coefficient Routine Investigation Machine and was developed at the Transport and Road Research Laboratory (TRRL) in Britain (see Figure 7). The smooth test wheel is inclined at 20° to the direction of travel. The road is wetted from the water tank on the truck and the test wheel moves continuously over this wetted surface, recording the sideways thrust exerted on the tyre by the road. The relation between the sideway-force and the normal load on the wheel is termed the sideway-force coefficient of friction (sfc). The test wheel rotates at one-third of the angular velocity of a wheel that runs straight and the friction developed may be measured continuously. The sideway force type of measurement determined the lateral friction which is available to a vehicle when it moves in a circular path such as traversing a curve or when it executes a passing manoeuvre. A rough correlation exists between the bfc and sfc results obtained on the same surface.

(c) **Pendulum tester.** The portable pendulum tester, also developed by the TRRL, is shown in Figure 8. The instrument is set up so that the pendulum, which has a rubber slider, moves over the surface for a specified length. The pendulum swings from rest in a horizontal position and the energy loss which occurs as it moves over the surface is a measure of the friction. This is read off directly from a calibrated scale. This instrument can be used to obtain an indication of the skid-resistance for stopping from low (= 50 km/h) speeds.

The property of the road surface that contributes directly to its skid-resistance is the component of the shape of its profile which has a wavelength less than the length of the area in contact with the vehicle tyre.
This depends chiefly on the texture of the stone and bitumen mixture comprising the surface. Two important parameters of the profile shape have been defined as the macrotexture and the microtexture.

The **macrotexture** refers to the separation between the stones protruding from the surface. This allows water to escape from between the tyre and the road surface. This property is measured in terms of the **surface texture depth** by spreading a known volume of sand over the surface, measuring its area and calculating the average depth.

The **microtexture** refers to the harshness or roughness of the stones themselves. There is currently no quantitative measure of the microtexture, but this can be qualitatively assessed by examining the stones and determining if they are harsh and angular or smooth and rounded (stones which are smooth have generally become so through the polishing action of traffic and are thus said to be polished). Stones that are resistant to polish have a high **polished stone value (PSV)**.

The macrotexture is of overriding importance at high speeds (> 100 km/h) whereas the microtexture is of overriding importance at low speeds (< 50 km/h). Since the pendulum tester is an appropriate instrument for measuring skid-resistance for low speeds, it follows that it also provides a measure for the microtexture. In the absence of the facilities of the brake-force trailer or SCRIM, the pendulum value together with the surface texture depth constitute an alternative description of the skid-resistance.

Similar to the procedure used with riding quality, coefficients of skid-resistance can be monitored at regular intervals in order either to evaluate the performance of various surfacings in terms of their skid-resistance, or to identify roads which needs to be considered for an improvement of skid-resistance.

**Surface drainage**

The **surface drainage** of a road is the general ability of the road to keep its surface clear of water. This refers to the speed of the run-off of water
during rain and to the extent of ponding of water during and after rain. The former determines the film thickness of the water in the road which is an important factor affecting the skid-resistance whereas the latter is a hazard in the form of water thrown up, especially by fast moving traffic. The function of good surface drainage is also to keep the road surface clear of grit wasted on to the road from the verges. Figure 9 gives an example of section of road covered with grit and with ponding of water.

The surface drainage is determined by the crossfall of the surface, the presence of any deformation of the surface, the capacity of the drainage system and the adjacent land drainage characteristics. The effectiveness of these factors in facilitating surface drainage is the measure of the serviceability of the road in terms of surface drainage. No means have yet been determined for quantifying this effectiveness, although design requirements are given by several authorities. Furthermore, the only factor to change during the life of a road is the deformation of the surface and thus it is only by this that the performance of the road in terms of surface drainage is meaningful. Terminal levels of surface drainage are usually determined subjectively by inspection during rain taking into account the rainfall characteristics of the area.

Note that ponding of water on the surface is undesirable also in that it allows time for water to penetrate through the surface into the pavement structure. However, this consideration is not important in a functional evaluation.

**Geometric properties**

The geometric properties refer to are those aspects of the geometric design of the road that affect the average safe speed of vehicles travelling on it and to the geometry of specific features that constitute a traffic hazard. The average speed of vehicles will vary during the day according to the traffic volume. Three or more speeds may be defined to describe the situation, these are the free speed, the peak traffic speed and the mean off-peak, day-time speed. The free speed of a road refers to the average speed that various vehicles can attain over the length of the road provided they have unrestricted use of the lane in which they are travelling. Though
the use of the lane is defined to be unrestricted, the driver of the vehicle is still regarded to be travelling in such a way that he is prepared to make an emergency stop should some obstacle be blocking the lane. The peak traffic speed is defined as the average actual speed vehicles can attain during periods of peak traffic density. The mean off-peak, day-time speed is the average actual speed attained by traffic during the day under "normal" (not peak) traffic densities.

The free speed of a road is determined by the lane width, by the horizontal curvature and super elevation of the road, by the gradient and by the sight distance. The sight distance is affected by the alignment of the road and by any road side furniture or natural object such as a tree that may obscure the view around curves.

The actual speed during real traffic conditions is determined by the traffic density, by the number of lanes (this includes passing lanes on upgrades), by the free speed per lane and by the capacity of road junctions.

In general it is true that drivers tend to drive at speeds which are in balance with the risk they are willing to accept of having an accident. Thus the general safety of a road cannot be determined independently of the determination of the free speed. There are, however, certain geometric properties of a road which may add to or detract from its safety when the general alignment of the road is designed for a particular free speed. These are, inter alia, the number and geometry of the merging, diverging and cutting junctions, the shoulder widths, the geometry of railway crossings and the widths of structures and the provision of safety devices such as crash barriers and collapsing road furniture.

The geometric properties of a road is the most important feature of the serviceability of a road, but is particularly difficult to quantify entirely. Values which are of particular interest to the traffic engineer are the free speed (for comparison with the accepted legal speed limits) and the peak traffic speed (for comparison with the lowest desirable speeds for those conditions). On the other hand he may be interested in the traffic
capacity of the road which is the maximum traffic density of the road at the minimum desirable speed for peak hour traffic. The traffic capacity may then be compared with the existing traffic density.

Additional values for describing the serviceability in terms of the geometric properties are by specifying minimum tolerable standards of road junctions, railway crossings, shoulder widths etc. and then to determine the degree to which a given road does not comply with these and thus determine additional roads needs. Alternatively the number of accidents attributable to the geometric properties may be recorded.

The geometric properties are permanent 'built-in' characteristics of the road and as such are not normally connected with the problem of maintenance in the sense of deterioration of the pavement. The performance of a road in terms of the geometric properties could however be expressed by the trend of the peak traffic speeds (for example) with time, or by the number of accidents attributable to the geometric properties with time.

4. MECHANISTIC EVALUATION

The estimation of the future performance of a pavement can be considered to result from the following process. First a mechanistic evaluation is made of the pavement condition based on various relevant measurements or observations of the pavement condition. A list of such measurements constitutes a mechanistic description of the pavement condition whereas the result of the mechanistic evaluation is a measure of the structural capacity of the pavement. Second, evaluations are made of the climatic and traffic conditions and factors are given representing these conditions. Third, the present serviceability is measured. A functional relationship is then assumed which can be given conceptually as

\[ P_t = f(t; S, C, T, P_0) \]  (1)

where

- \( P_t \) = serviceability at time \( t \)
- \( S \) = structural capacity
- \( C \) = climatic factors
- \( T \) = traffic factors
- \( P_0 \) = present serviceability
A well known example of equation (1) is that used in the estimation of the life of a road using the AASHO Road Test definition of structural number. Here \( S \) is given in terms of the structural number of the pavement, \( C \) is the regional factor, \( T \) is the present traffic volume (in number of equivalent 80 kN axle loads) together with a growth factor and \( P \) is the riding quality. It is usual in this application to set \( P_t \) as the terminal level of riding quality and to calculate \( t \) which then represents the design life of the pavement.

In general it will not always be possible to obtain a value for \( S \) objectively from established relationships such as that for the structural number. This is especially true if the evaluation is done at a time when the pavement has deteriorated considerably when many extra factors should be considered and weighed up subjectively (for example the extent of cracking). Similarly the function \( f \) may also refer to a subjective assessment of \( P_t \) by considering the effects of \( S \), \( C \), \( T \) from local experience. However, formally or informally the structure of equation (1) is always implicit in engineering decisions regarding maintenance, road needs or the design life of a pavement.

A comprehensive mechanistic description of the pavement is the set of measured values of the pavement condition which are relevant to the determination of its structural capacity. These values can be grouped under five categories which are measurements of structural response, material properties, surface integrity, drainage and distress. These are discussed in the following and summarised in Table II.

(a) **Structural response.** By this is meant the stresses and strains that are induced in the pavement by loading on the surface. Measurements relating to the structural response are those of deflection, radius of curvature, elastic moduli and layer thicknesses.

(b) **Material properties.** Material properties are used here in the sense of the reaction of various pavement materials to stresses, strains and the presence of water. These properties include measurements of stability, fatigue life, plasticity index, CBR, crushed stone value and polished stone value.
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<thead>
<tr>
<th>CATEGORY</th>
<th>EXAMPLES</th>
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<td>Deflection</td>
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<td>Radius of curvature</td>
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<td></td>
<td>Elastic moduli</td>
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<td>Layer thicknesses</td>
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<td>2. Material properties</td>
<td>Stability</td>
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<td></td>
<td>Plasticity index</td>
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(c) **Surfacing integrity.** This is a measure of the condition of the surfacing as an intact and durable matrix. It includes values of porosity and texture.

(d) **Drainage.** This is a measure of the ability of the pavement to drain free water from the pavement. It includes measurements of the cross-fall of the surface and culvert capacities, and estimations of the efficiency of subsurface drainage.

(e) **Distress.** Distress is the visible manifestation of the deterioration of the condition of the pavement with respect to either the serviceability or the structural capacity. Distress measurements are usually convenient since they do not require instruments. They are also particularly important in a mechanistic evaluation because, first, the development of distress introduces a reduction in the structural capacity of the pavement and second, the presence of distress is a clear indication of weaknesses in the pavement. For these reasons detailed attention is given to concepts used in the classification and description of distress in Appendix I.

Note that although a mechanistic evaluation is always based on a mechanistic description of the pavement condition, it is not always possible or economical (or even necessary) to obtain a comprehensive description. Usually decisions as to the extent of the data necessary for a particular evaluation are made sequentially. By observing the distress on the pavement and judging its mechanism and cause, further measurements are made of other factors. Based on these measurements others may be prescribed until further measurements are considered unnecessary or uneconomical.

Note also that some factors are given in both Table I and in Table II. Even though these factors may be recorded identically they are used for different purposes. For example, rut depth is used in the evaluation of riding quality in so far as it is a measure of the unevenness of the road surface and as such affects vehicle behaviour. On the other hand, when predicting the future performance of the pavement, the rut depth is a measure of the stability of the pavement in terms of its traffic history. Furthermore, under certain conditions, a rut depth of 20 mm is an indication
that the pavement will deteriorate rapidly because cracking usually develops at this level of deformation.

Although the estimation of future performance is always implicit in evaluating the maintenance needs of a road, it is not always followed through explicitly in determining maintenance strategies. Of greater significance may be the estimation of the development of distress itself under the given conditions. This is because

(a) different forms of maintenance are required for different types of distress;

(b) the serviceability generally decreases rapidly with the deterioration of the condition of the pavement; and

(c) as a rule-of-thumb the cost of maintenance increases rapidly with the development of primary and secondary distress.

Note that these are very generalised remarks. The significance of cracking, for example, with respect to future performance and thus to maintenance requirements depends very much on many other factors (such as climate, traffic, etc.). Considerable research is needed to determine optimum maintenance strategies under various circumstances.

It is thus clear that the interpretation of descriptions of pavement condition depends on the purpose for which the information will be used. This is especially true when defining a failure condition, as will be discussed in the following section.

5. LIMITING VALUES OF PAVEMENT CONDITION

Terms such as "failure criteria", "failure condition", "the road has failed" are commonly used in practice and in the literature without clear definitions always having been given to their meanings. To say the road has failed generally suggests that some distress is evident on the road but does not usually indicate the seriousness of the distress. In some cases it does imply that maintenance measures are immanently required for the road. Failure criteria or failure conditions usually refer to some limiting level of distress which is needed for some particular purpose. These purposes
may be the study of a road from a functional mechanistic, maintenance or research point of view. The use of the phrase "failure of a pavement" can thus be vague, ambiguous and confusing and should thus be avoided. The following defines various uses and terms of limiting values of pavement condition.

Terminal values of serviceability relate to limiting values with respect to safety, speed or comfort. If the serviceability of a road is below the accepted terminal level for the particular class of road, this defines a need for that road with respect to user requirements. Specifically, one may refer to terminal values of riding quality, skid-resistance or geometric requirements.

On the other hand, a road may receive certain maintenance measures long before it has reached the terminal level of serviceability. This would be because the state of distress and the particular traffic and environmental conditions are such that it would be more costly to implement some major maintenance measure in the future than the relatively minor maintenance needed earlier to arrest the development of distress*. If a road has reached a limiting level of distress which is defined as that level at which it is most profitable to implement some maintenance measure, it is said to be in a critical state of distress with respect to maintenance. If the road is left until the distress increases beyond the critical state, the road can be said to be in a severe state of distress.

A further use of limiting values of pavement condition is that extensively used in research work into the design of new pavements or maintenance measures. Here a pavement (or some component of the pavement) is designed in order to meet a minimum standard over a given period of time. This standard may be a functional requirement or a given trend of distress. If the period of time to reach this level is less than the time prescribed by the design, this can be referred to as a design failure. The minimum

*This applies in the case of riding quality where distress such as cracking can cause a deterioration in serviceability, even though the state of cracking remains unchanged. In the case of skid-resistance, however, only a deterioration of the distress itself, e.g. fatting, can bring about a change in serviceability: there is therefore no need to carry out maintenance much before the terminal level of serviceability is reached.
standard may be referred to as the *limiting criterion* of the design. Examples of such limiting criteria are:

(a) The use of a terminal level of riding quality in the AASHO road test. Here the objective of the design was the preservation of an acceptable level of riding quality under conditions of minimal maintenance.

(b) The use of a limiting value of rut depth by the TRRL to compare the resistance of various pavement structural designs to deformation. This value is related to their definition of a critical state of distress with respect to overlay requirements for roads.
APPENDIX I

ATTRIBUTES OF DISTRESS

Modes and types of distress

Distress is manifested in one of six modes:

(a) Deformation: the development of a change (unevenness) in the road surface profile.

(b) Fracture (cracking).

(c) Loss of stone: this is defined as the loss of stone from a surfacing.

(d) Potholing: this is regarded as a distinct and separate mode of distress rather than as an advanced state of fracture or loss of stone. It includes breaking of the road edges.

(e) Loss of surface texture depth.

(f) Polishing of stone.

Some of these modes can be sub-classified into various types of distress. Fracture can be classified as crocodile cracking, transverse cracking, longitudinal cracking, etc.; deformation as ruts, depressions, corrugations etc.; and loss of surface texture depth as wearing of stone, fatting or embedment of stone. Examples of types of distress with respect to each mode are listed in Table III and are discussed further below.

Degree and extent of distress

Important measures of distress are its degree and extent. The degree of distress is a measure of its severity. For example in the case of cracking the severity is determined by the crack width. The severity can be indicated by a class number 1 to 5 where Degree 1 would indicate the first evidence of a particular mode (or type) of distress and Degree 5 would indicate the severest degree of distress, or by specifying the degree directly, for example, in the case of cracking, a crack width of 3mm.

The extent of distress is given by the proportionate length or area of road affected. This can be given directly by stating for example...
<table>
<thead>
<tr>
<th>MODE OF DISTRESS</th>
<th>TYPE OF DISTRESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deformation</td>
<td>Depressions</td>
</tr>
<tr>
<td></td>
<td>Mounds</td>
</tr>
<tr>
<td></td>
<td>Ruts</td>
</tr>
<tr>
<td></td>
<td>Ridges</td>
</tr>
<tr>
<td></td>
<td>Corrugations</td>
</tr>
<tr>
<td></td>
<td>Distortion</td>
</tr>
<tr>
<td>Fracture</td>
<td>Transverse cracks</td>
</tr>
<tr>
<td></td>
<td>Longitudinal cracks</td>
</tr>
<tr>
<td></td>
<td>Block cracks</td>
</tr>
<tr>
<td></td>
<td>Ladder cracks</td>
</tr>
<tr>
<td></td>
<td>Crocodile cracks</td>
</tr>
<tr>
<td></td>
<td>Parabolic cracks</td>
</tr>
<tr>
<td></td>
<td>Star cracks</td>
</tr>
<tr>
<td>Loss of stone</td>
<td></td>
</tr>
<tr>
<td>Potholing</td>
<td>Potholes</td>
</tr>
<tr>
<td></td>
<td>Edge breaks</td>
</tr>
<tr>
<td>Loss of surface texture depth</td>
<td>Fatting</td>
</tr>
<tr>
<td></td>
<td>Embedment</td>
</tr>
<tr>
<td></td>
<td>Wearing</td>
</tr>
<tr>
<td>Polishing</td>
<td></td>
</tr>
</tbody>
</table>
that 40 per cent of the road (under review) is cracked. Alternatively the extent of distress can be expressed as a number where

Area (or Length) 1 indicates that less than 10 per cent of the area (linear length) is affected
Area (or Length) 3 indicates that between 10 per cent and 80 per cent of the area (linear length) is affected.
Area (or Length) 5 indicates that more than 80 per cent of the area (linear length) is affected.

A further useful measure of extent especially for rapid inspection surveys is the number of small affected areas and the number of large affected areas in the section of road under review. A small area is defined as less than 10 m² and a large area as greater than 10 m².

Stipulating the number of potholes in a given section is a useful way of indicating the extent of this form of distress (see below).

It often happens that a particular type of distress may be evident on a section of road in varying degrees of severity. In such cases the extent of all the distress of that type from the lowest to the highest degree should be recorded. For example, cracking of a certain section may be described as Degree 4 Area 1 and Degree 2 Area 5. The notation Degree 2 Area 5 thus indicates that more than eighty per cent of the road was in a state of distress of at least Degree 2 (i.e. Degree 2 and greater). Where a linear length specification is a more suitable measure of extent (such as in the case of longitudinal cracking) the distress would be described for example as Degree 4 Length 1 and Degree 2 Length 5.

Finally for potholes one might have the description: Degree 5 Number 6 and Degree 3 Number 11.

Position and spacing of distress

The position and spacing are further descriptive attributes of distress. The position is usually expressed as the edge (e.g. edge cracking), the wheel path (e.g. rutting in the wheel path), centre line or the lane centre. The spacing is usually (but not exclusively) used in connection with fracture. It refers in general to the distance between cracks in the
cracked area. The spacing is indicated by, for example, Spa. 1 m where cracks are spaced 1 m apart. This will be discussed in greater detail below for each type of fracture.

**Cause and mechanism of distress**

The cause of distress refers to an extraordinary circumstance or condition which was necessary for the distress to occur. Examples of causes of distress are the intrusion of water (through, for example, inadequate drainage), unstable materials, excessive loading, underdesign and hardening of the binder. The mechanism of distress is the physical process by which the cause of distress results in the distress. Examples of mechanisms of distress include shear, heave, consolidation, fatigue, shrinkage, plastic flow and pumping.

To a large extent the identification of the cause and mechanism of distress is an alternative to or an aid in the determination of the structural capacity and in this respect is to some extent a mechanistic evaluation of the pavement.

**Pavement components**

In explaining the cause and mechanism of distress it is usually necessary to refer to one or more of the components of the pavement. These are the shoulder treatment, surface treatment (or surfacing), base, subbase subgrade and fill. These are illustrated in Figure 10.

**TYPES OF DISTRESS**

1. **Deformation**

   **Degree**

   Deformation is a change in the road surface profile. This can be manifested as an area of road having its surface either below or above that of the original pavement. The degree of distress is determined by measuring the maximum deviation under a 2 m straightedge as illustrated in Figure 11. The classes of degree are:

4/......
The types of deformation are defined in the following:

(a) Depressions:
Depressions are localised areas of pavement with elevation lower than the surrounding area.

(b) Ruts:
Ruts are depressions extended in length and confined in width. These usually occur in a longitudinal direction and in the wheel path. They are depressions that are generally deeper than 1 in.

(c) Mounds:
Mounds are localised areas of pavement with elevation higher than the surrounding area. They are generally less than 1 in. high and are usually associated with active subgrades or the settlement of a fill.

(d) Corrugations:
Corrugations are regularly spaced transverse undulations of the pavement consisting of valleys and crests less than 1 in. apart. Non-localised corrugations occur in lengths varying from 1 in. to 1 foot and rise to a height of less than 1 in.

(e) Ridges:
Ridges are mounds extended in length and confined in width. They are usually associated with active subgrades or settlement of a fill.

Degree 2 - 10 to 20 mm
Degree 3 - 20 to 30 mm
Degree 4 - 30 to 40 mm
Degree 5 - greater than 40 mm

Figures 11 to 17 illustrate various examples of deformation. Indications are given of various attributes of the distress where possible and applicable.
(c) **Block cracks.** Cracks in a block or rectangular pattern. The spacing is given as the average of the shorter distance between the sides of the blocks. (Where the spacing is relatively large i.e. in the order of 4 or 5 metres the block cracking usually occurs through a combination of transverse and longitudinal cracking (often by the shrinking of a stabilised base or subbase). Where the spacing is relatively small i.e. less than 1 m the cracking usually occurs through the hardening of the binder in the surfacing and subsequent thermal shrinkage).

(d) **Ladder cracks.** A particular type of block cracking formed by two initial longitudinal cracks (about 2 m apart) with subsequent transverse cracks forming between them giving the appearance of a ladder.

(e) **Crocodile cracks.** Cracking in a polygon pattern resembling that of the hide of a crocodile. (It may occur directly through the fatigue of the surfacing by the action of traffic or as secondary cracking around primary line cracks). The spacing is the average least diameter of the polygons.

(f) **Parabolic cracks.** Cracks of a parabolic shape. (Usually caused through the slippage of the bituminous surfacing due to the horizontal forces of traffic and therefore more common on sections where rapid acceleration takes place or on steep up-grades).

(g) **Star cracks.** Cracks radiating from a point. (Occurs through blistering by the accumulation of material beneath the surfacing or as a first stage of crocodile cracking.

**Examples**

Figures 18 to 31 illustrate various examples of fracture. Indications are given of various attributes of the distress where applicable.

3. **Loss of stone**

**Degree**

Loss of stone occurs where individual stones are lost from the surfacing. In the case of thin surface treatments this results in exposure
of the underlying layer and if this is an unbound layer potholing follows. In the case of a premix surfacing, the surfacing gradually disintegrates after which it eventually cracks, spalls and develops potholes. A single surface treatment consists of one layer of single size stones and consequently any loss of stone exposes the underlying layer directly. A multiple surface treatment consists of several layers of stone of successively smaller size and loss of stone is characterised by the loss of the fine stones on the surface followed by the loss of the larger stones in successively exposed layers. A premix surfacing consists of a mixture of stones of various sizes. The fine stones on the surface are lost first followed by the loosening and loss of the larger stones. This is repeated as the premix layer disintegrates. Because of the different manifestations of the distress in different surfacings, care must be taken when recording loss of stone to identify and record the type of surfacing inspected. Furthermore, the degree of distress is defined in terms of the type of surfacing as given in the following:

<table>
<thead>
<tr>
<th>SINGLE SEALS</th>
<th>MULTIPLE SEALS</th>
<th>PREMIX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree 1 No discernable loss of stone</td>
<td>No discernable loss of stone</td>
<td>No discernable loss of stone</td>
</tr>
<tr>
<td>Degree 2 *</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Degree 3 *</td>
<td>Loss of the stones on the third layer of a triple seal</td>
<td>7-12 mm disintegration of premix</td>
</tr>
<tr>
<td>Degree 4 *</td>
<td>Loss of second layer of triple seal or first layer of double seal</td>
<td></td>
</tr>
<tr>
<td>Degree 5 Loss of stones</td>
<td>Loss of stone from all layers</td>
<td>Disintegration &gt; 12 mm</td>
</tr>
</tbody>
</table>

*This degree is not defined for this type of surfacing.
Note that the seriousness of the mode of distress is the loss of the integrity of the road surface resulting in a loss of imperviousness and in potholing. In many cases however loss of stone may occur without any serious consequences. Examples are:

(a) The loss of the top layer of a triple seal leaving behind an impervious and durable double seal because of a fault in the application of the top layer alone;

(b) the loss of some stone from a single surface treatment over a premix surfacing (because, for example, of insufficient precoating) retaining an impervious surface with adequate skid-resistance. In such cases it is important to record the good state of the surface along with the degree of loss of stone.

**Mechanism**

Loss of stone occurs through the fracture of the binder (ravelling) or loss of adhesion between the stone and the binder or the fracture of the stone. Where the stone has been separated from the binder by the action of water, the mechanism is said to be stripping.

**Extent and spacing**

The extent of loss of stone is given as usual by the total proportion of area affected. In some cases, particularly in the case of single seals it is important to give the geometry in terms of the spacing. The spacing is defined for this mode of distress as the average diameter of the patches in which stone has been lost. For example loss of stone from a single seal, Degree 5 Area 1 Spa. 10 mm indicates that less than 10% of the stone has been lost in the form of isolated single stones (see Figure 34). Other examples of the loss of stone from a single seal are given in Figure 35, Figure 36 and Figure 37.

4. **Potholing**

Potholing is the loss of pavement material (other than the stones from the surfacing) through the crumbling (spalling) of the surfacing and sub-
sequent layers. The two types of this mode of distress are potholes - the cylindrical holes found in pavements, and edge breaks - the breaking away and loss of premix surfacings at the edge of the road. Note that it is not usual to refer to the loss of a surface seal in a circular patch as a pothole if the underlying layer has not been affected.

If necessary the degree of potholing can be expressed by a combination of the diameter of the potholes (or the distance breaking has occurred from the edge of the pavement) and the depth. The various classes of the degree of potholing are:

- **Degree 1** - no sign of spalling
- **Degree 2** - spalling of surfacing, small potholes < 50 mm
- **Degree 3** - potholes between 50 and 150 mm
- **Degree 4** - large potholes (> 150 mm) up to 50 mm deep
- **Degree 5** - large potholes deeper than 50 mm

The extent of potholing would normally be given by the "number" attribute in the case of potholes and the "length" attribute in the case of edge breaks.

5. **Loss of surface texture depth**

Degree and extent

Loss of surface texture depth occurs when the size of the asperities between the stones in the surfacing (i.e. the macrotexture) is reduced. This also results in a reduction in skid-resistance. Texture depth is measured by the sand patch test (see page 9). The measurement of this form is distress is complicated by the very different textures obtained in the different forms of newly laid surfacings (e.g. single surface treatments, multiple surface treatments, dense graded asphalt, gap-graded asphalt with precoated chippings etc.). A common scale for the degree of loss of surface texture for all types is however desirable, and the following scale is defined with a view to the distress as it affects skid-resistance.
<table>
<thead>
<tr>
<th>TEXTURE DEPTH</th>
<th>VISUAL APPEARANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree 1</td>
<td>above 1,0 mm</td>
</tr>
<tr>
<td>Degree 2</td>
<td>0,6 - 1,0 mm</td>
</tr>
<tr>
<td>Degree 3</td>
<td>0,3 to 0,6 mm</td>
</tr>
<tr>
<td>Degree 4</td>
<td>0,0 to 0,3 mm</td>
</tr>
<tr>
<td>Degree 5</td>
<td>0,0</td>
</tr>
</tbody>
</table>

Degree 1 represents a texture depth that would be considered adequate for skid-resistance of roads carrying high speed traffic whereas Degree 5 indicates the worst possible condition for skid-resistance for all roads. This degree denotes a fat surface (fatting is defined as a type of this mode of distress and is discussed below) and thus is not the most severe form of all types of this distress. Furthermore, in, for example, a dense-graded asphalt a surface-texture denoted by Degree 1 (and possibly Degree 2) cannot be attained even if there is no sign of distress. In such cases - in the event of having no fatting (for example) and no onset of fatting is visible - it is recommended that instead of recording "Fatting, Degree 2", either "no fatting" or "Fatting, Degree 0" should be recorded.

The extent of loss of stone can be given either in the "Area" attribute where it indicates the proportion of the area affected or where the distress is confined to the wheel tracks, by the "Length" attribute.

Types

(a) **Fatting.** Fatting is evident when the binder rises to the surface thus reducing the surface texture depth. It is characterised by a rich, black (and slick in the cases of Degree 4 and Degree 5) appearance. It can occur in a premix surfacing through compaction of the layer by traffic or in a surface treatment when too much binder has been sprayed or when the stones are pressed into the underlying layer. Apart from the extent of fatting the geometry of the fatted patches is also of interest since whether it is made...
up of small or large patches is of importance to the general skid-resistance of the road. The geometry is indicated by the spacing which refers to the average smallest diameter of the fatted patches. When designing remedial treatments for fatted surfaced of Degree 3, the thickness of the film of bitumen is an important consideration. In such cases the thickness of this film should be measured with the aid of a sharp instrument. In premix surfacings the spacing of the fatted patches may provide an indication of the thickness of bitumen film since for such surfacings a rough correlation between thickness of film and size of fatted patch has been noted.

(b) Embedment. Embedment occurs when the stones on the surface get pressed into the surfacing* by the action of traffic without the bitumen flowing to the surface. It is characterized by a low texture depth without the stones being worn and with a dry appearance of the surfacing. This type of distress can occur with gap-graded asphalt with precoated chippings.

(c) Wearing. The breaking off or wearing down of the stone asperities. This may occur through the action of wheels with studded tyres (a situation which is not a problem in South Africa) or the wearing down of the stone by the abrasive action of traffic. After the surfacing has worn completely smooth (Degree 4) the surfacing itself begins to wear away and become thinner, but this has little added significance to skid-resistance or to maintenance. Thus the highest degree of wearing would be Degree 4.

Examples

Examples of a fatty surface are given in Figure 40 and 41.

*Stones pressed into an underlying layer is a mechanism of fattting and is also commonly referred to as embedment. However, so as not to cause confusion the work embedment is reserved in this text for the type of distress defined above.
6. Polishing

Polishing is the wearing smooth of the stones on the surface of the road (i.e. the reduction of microtexture) with a concomitant reduction in skid-resistance. The degree of polish can be estimated by the pendulum tester (see page 8). The classes of the degree of polish are defined as:

Degree 1 - greater than 75* (stones very harsh; sharp to the touch)
Degree 2 - 75 to 55
Degree 3 - 55 to 45 (stones sharp and angular but not harsh to the touch)
Degree 4 - 45 to 35
Degree 5 - below 35 (stones rounded and smooth to the touch)

Figure 42 gives an example of a surfacing with no polishing whereas Figure 43 gives an example of a high degree of polish.

*These figures are expressed in units of the pendulum tester.
APPENDIX II

AD HOC PAVEMENT DESCRIPTIONS

It is generally impossible to give a detailed description of the pavement condition for all sections of road since this would be exorbitantly costly and time-consuming. Careful thought must therefore be given to those details that are necessary and economically justifiable for a particular study. The following gives three examples of approaches that may be adopted when more than one factor of the pavement condition may be of interest.

(a) Example of a detailed description of distress. In some cases it may be necessary for an engineer to have a detailed description of the distress of a small section of pavement. Such a case may arise when he has to make a recommendation as to some corrective measure without being able to visit the site. An example of such a description is:

"Cracking of the premix surfacing and pumping of fines from the subbase. Longitudinal and transverse cracking of degree 4 at 3 m spacing over 40% of the area; crocodile cracking of degree 3 at 100 to 300 mm spacing over 40 per cent of the area. The longitudinal and transverse cracking probably originated from shrinkage due to cement stabilisation of the base, aggravated by the settlement of a high fill, and the subsequent crocodile cracking to fatigue under traffic, worsened by the presence of the shrinkage cracks and ingress of rainwater.

(b) Example of inspection sheet for condition surveys of a road network. In this example a particular road authority has decided to undertake regular condition surveys in order to assess the roads needs of its network. It is considered impractical to execute a detailed pavement evaluation of the whole network and the following factors were chosen as being justified for the purpose of a road needs evaluation.

*Such a description will include those attributes of the distress that are relevant and are possible to obtain from a visual inspection. These are given in the example and are indicated in the following:
*1 - mode of distress
*2 - pavement component
*3 - mechanism
*4 - type of distress
*5 - degree, spacing, extent
*6 - cause
(i) Functional aspects: riding quality, skid-resistance.
(ii) Mechanistic aspects: deflection (structural response), cracking (distress), patching (distress).

Since one of the requirements here is a high speed of recording, only cracking of Degree 3 or higher is considered, as Degree 3 is the lowest degree that is visible in a vehicle travelling at normal traffic speeds. Patching is regarded for this purpose as an indication of a pavement weakness. It is assumed the patching was done to repair sections of road damaged by fracture. After patching, the road still maintains its previous structural weakness which lead to cracking, but the impermeability of the road is restored. Table IV gives an example of the type of inspection sheet used in such a survey.

Examples of such inspection sheets abound in the literature. Each road authority must decide for itself the details which will suit its purpose best. What, however, must always accompany such a scheme is a clear stipulation of how the information is to be used.

(c) Example of a rating scale of the pavement condition confined to the requirements of a specific experiment. Two types of distress are of importance in the evaluation of an experiment to assess the correct amount of bitumen to be used in a single surface seal. These are:

(i) loss of stone;
(ii) fatting.

If the mix is too rich in bitumen fatting will occur and if too lean loss of stone will occur. In order to rate the degree of success of the various bitumen contents after a given period of time, each condition of loss of stone or fatting is ranked according to its need for maintenance by the symbols:

- VG - very good (no need of maintenance)
- G - good
- FG - fairly good
- F - fair (road unsatisfactory, requires immediate maintenance)
- P - poor
- B - bad (road in a state of severe neglect)
### TABLE IV

**EXAMPLE OF AN INSPECTION SHEET FOR A RAPID ROAD NEEDS SURVEY**

**LOCATION**

<table>
<thead>
<tr>
<th>DISTANCE*</th>
<th>FUNCTIONAL ASPECTS</th>
<th>MECHANISTIC ASPECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SKID-RESISTANCE</td>
<td>RIDING QUALITY</td>
</tr>
</tbody>
</table>

*In increments of 0.1 km

†95 percentile of deflections measured in 0.1 km

**"Area" attribute of cracking of Degree 3 and above

++Area attribute of patching
The further symbol + indicates that the distress is fatting whereas the symbol _ indicates loss of stone. Since fatting and loss of stone are generally mutually exclusive (indicating opposite poles in the bitumen content) only one of the symbols + or _ will be used for a given pavement. An example of how these symbols may be assigned to pavements in the case of fatting according to the experience of the engineer concerned is given in Table V. The case for loss of stone (for a single seal) is given in Table VI. For a given size of stone laid under similar conditions, the symbols are expected to correlate with the bitumen content in the following way:

\[
\begin{array}{c}
\text{B} - \text{P}_- \text{F}_- \text{FG} - \text{G}_- \text{VG} \text{G}_+ \text{FG}_+ \text{F}_+ \text{P}_+ \text{B}_+ \\
\text{Increasing bitumen content}
\end{array}
\]

### Table V

**EVALUATION OF THE FATTING ACCORDING TO ITS DESCRIPTION**

<table>
<thead>
<tr>
<th></th>
<th>AREA 1</th>
<th>AREA 3</th>
<th>AREA 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree 1</td>
<td>VG</td>
<td>VG</td>
<td>VG</td>
</tr>
<tr>
<td>Degree 2</td>
<td>VG</td>
<td>VG</td>
<td>VG</td>
</tr>
<tr>
<td>Degree 3</td>
<td>VG</td>
<td>G</td>
<td>FG</td>
</tr>
<tr>
<td>Degree 4</td>
<td>G</td>
<td>F</td>
<td>P</td>
</tr>
<tr>
<td>Degree 5</td>
<td>G</td>
<td>FG → P</td>
<td>B</td>
</tr>
</tbody>
</table>

### Table VI

**EVALUATION OF THE LOSS OF STONE ACCORDING TO ITS DESCRIPTION**

<table>
<thead>
<tr>
<th>SPACING</th>
<th>AREA 1</th>
<th>AREA 3</th>
<th>AREA 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>VG</td>
<td>VG</td>
<td>VG</td>
</tr>
<tr>
<td>0 → 20 mm</td>
<td>G</td>
<td>FG → F</td>
<td>P</td>
</tr>
<tr>
<td>20 → 100 mm</td>
<td>FG</td>
<td>F → P</td>
<td>B</td>
</tr>
<tr>
<td>100 → 500 mm</td>
<td>FG</td>
<td>P → B</td>
<td>B</td>
</tr>
<tr>
<td>&gt; 500 mm</td>
<td>FG</td>
<td>P → B</td>
<td>B</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------------</td>
<td>------------------------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AASHO PSI</td>
<td>The PSI obtained by the equation established during the AASHO experiment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area of distress</td>
<td>A measure of the extent of distress</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attributes of distress</td>
<td>The various aspects taken into account when describing distress</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block cracks</td>
<td>A type of distress* of the mode &quot;fracture&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BPR roughometer</td>
<td>An instrument for assessing riding quality developed by the Bureau of Public Roads of the USA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brake-force trailer</td>
<td>An instrument for assessing skid-resistance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cause of distress</td>
<td>An extraordinary condition or set of circumstances necessary for the occurrence of the distress</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHLOE profilometer</td>
<td>An instrument for assessing riding quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of friction</td>
<td>The ratio of the force of frictional resistance and the force normal to the contact plane at which the friction occurs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of skid-resistance</td>
<td>Coefficients of friction obtained by instruments used to assess skid-resistance under conditions similar to those experienced by skidding vehicles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Component, pavement</td>
<td>One of the various layers comprising the pavement structure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrugations</td>
<td>Type of distress* of the mode &quot;deformation&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crocodile cracks</td>
<td>Type of distress* of the mode &quot;fracture&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deformation</td>
<td>A mode of distress, the manifestation of unevenness of the surface profile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Degree of distress</td>
<td>A measure of the severity of the distress</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depressions</td>
<td>Type of distress* of the mode &quot;deformation&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distortions</td>
<td>Type of distress* of the mode &quot;deformation&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distress</td>
<td>The manifestation of the deterioration of the pavement with respect to either the serviceability or the structural capacity</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*The types of distress are defined further, with the aid of photographs, in Appendix I.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edge breaks</td>
<td>Type of distress* of the mode &quot;potholing&quot;</td>
</tr>
<tr>
<td>Embedment</td>
<td>Type of distress* of the mode &quot;loss of surface texture depth&quot;</td>
</tr>
<tr>
<td>Extent of distress</td>
<td>Proportion of the pavement exhibiting this distress or the frequency of occurrence of the distress</td>
</tr>
<tr>
<td>Fattening</td>
<td>Type of distress* of the mode &quot;loss of surface texture depth&quot;</td>
</tr>
<tr>
<td>Fracture</td>
<td>A mode of distress, the manifestation of cracking of the asphalt surfacing</td>
</tr>
<tr>
<td>Free speed</td>
<td>The average speed that the various vehicles travelling over the given section of road could attain with unrestricted use of their lane</td>
</tr>
<tr>
<td>Functional description</td>
<td>Description of the condition of a road in terms of its ability to fulfil its functional requirements</td>
</tr>
<tr>
<td>Functional evaluation</td>
<td>The assessment of the degree to which the road fulfils its functional requirements</td>
</tr>
<tr>
<td>Functional requirements</td>
<td>The requirements of a road from the point of view of the road user. These requirements are the comfort, safety and convenience that the road should provide in the transportation of vehicles</td>
</tr>
<tr>
<td>Geometric properties</td>
<td>Those aspects of the geometric design of a road that affect the average safe speed of vehicles travelling on it and to the geometry of specific features that constitute a traffic hazard</td>
</tr>
<tr>
<td>Ladder cracks</td>
<td>Type of distress* of the mode &quot;fracture&quot;</td>
</tr>
<tr>
<td>Large areas of distress</td>
<td>Areas greater than $10 \text{ m}^2$ showing a given type (usually crocodile cracks or loss of stone) of distress</td>
</tr>
<tr>
<td>Length of distress</td>
<td>A measure of the extent of distress</td>
</tr>
<tr>
<td>Longitudinal cracks</td>
<td>Type of distress* of the mode &quot;fracture&quot;</td>
</tr>
<tr>
<td>Loss of stone</td>
<td>A mode of distress, the occurrence of individual stones being lost from the surfacing of a road</td>
</tr>
</tbody>
</table>
Loss of surface texture depth: A mode of distress; the occurrence of a reduction in the size of the asperities normally caused by the size and separation of the stones on the road surface.

Macrotexture: The height and separation of stones projecting from the surface of the road.

Maintenance: A remedial measure to improve the serviceability (not usually the geometric properties) or the structural capacity of the road.

Maintenance priorities: A selection of certain maintenance tasks deemed of greater economic value than others.

Material properties: The reaction of various road building materials to changes in stress under varying conditions of moisture and density.

Mechanism of distress: The physical process by which the cause of the distress results in the distress.

Mechanistic description: A list of values of properties of the pavement relevant to a mechanistic evaluation.

Mechanistic evaluation: The assessment of the structural capacity of a pavement.

Microtexture: The degree to which the stones on the surface of a pavement are harsh and angular or smooth and rounded.

Modes of distress: The six major classes of distress.

Mounds: Type of distress* of the mode "deformation".

Number of distress: A measure of the extent of distress.

Parabolic cracks: Type of distress* of the mode "fracture".


Peak traffic speed: Average speed attained by vehicles during conditions of peak hour traffic densities.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance</td>
<td>The trend of serviceability with time</td>
</tr>
<tr>
<td>Polishing</td>
<td>A mode of distress, the wearing smooth and round of stones on the surface of the pavement</td>
</tr>
<tr>
<td>Position of distress</td>
<td>The situation of distress with respect to the surface of the road</td>
</tr>
<tr>
<td>Potholes</td>
<td>Type of distress * of the mode &quot;potholing&quot;</td>
</tr>
<tr>
<td>Potholing</td>
<td>A mode of distress, the loss of pavement material through the crumbling of exposed layers</td>
</tr>
<tr>
<td>PSI</td>
<td>Present serviceability index, a measure of riding quality obtained by the use of instruments</td>
</tr>
<tr>
<td>PSR</td>
<td>Present serviceability rating, an assessment of riding quality obtained by the use of a panel of raters</td>
</tr>
<tr>
<td>Ridge</td>
<td>Type of distress * of the mode &quot;deformation&quot;</td>
</tr>
<tr>
<td>Riding quality</td>
<td>The general extent to which road users experience, through the medium of their vehicles, a ride that is smooth and comfortable or bumpy and thus unpleasant and perhaps dangerous</td>
</tr>
<tr>
<td>Road needs</td>
<td>Deficiencies in the structural capacity or serviceability of the road</td>
</tr>
<tr>
<td>Rut</td>
<td>Type of distress * of the mode &quot;deformation&quot;</td>
</tr>
<tr>
<td>SCRIM</td>
<td>Instrument for the assessment of skid-resistance</td>
</tr>
<tr>
<td>Serviceability</td>
<td>A measure of the extent to which a particular road meets the requirements of the road user</td>
</tr>
<tr>
<td>Skid-resistance</td>
<td>The general ability of a particular road surface to prevent skidding of vehicles</td>
</tr>
<tr>
<td>Slope variance</td>
<td>A measure of the road surface profile; used in particular to obtain the AASHO PSI</td>
</tr>
<tr>
<td>Small areas of distress</td>
<td>Areas less than 10 m² showing a given type (usually crocodile cracks or loss of stone) of distress</td>
</tr>
<tr>
<td>Spacing</td>
<td>An attribute of distress pertaining to its geometry</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Star cracks</td>
<td>Type of distress of the mode &quot;fracture&quot;</td>
</tr>
<tr>
<td>Structural capacity</td>
<td>The ability of the pavement to withstand the effects of climate and traffic</td>
</tr>
<tr>
<td>Structural response</td>
<td>The stresses and strains introduced in the pavement by loading on the surface</td>
</tr>
<tr>
<td>Surface drainage</td>
<td>The general ability of the road to keep its surface clear of water</td>
</tr>
<tr>
<td>Surface texture depth</td>
<td>A measure of the macrotexture established by the sand patch test</td>
</tr>
<tr>
<td>Surfacing integrity</td>
<td>A measure of the condition of the surfacing as an intact and durable matrix. (It includes values of porosity and texture)</td>
</tr>
<tr>
<td>Terminal level</td>
<td>A minimum acceptable level of some feature of the road in terms of its serviceability</td>
</tr>
<tr>
<td>Traffic capacity</td>
<td>The maximum traffic density of the road at the minimum desirable speed for peak hour traffic</td>
</tr>
<tr>
<td>Transverse cracks</td>
<td>Type of distress of the mode &quot;fracture&quot;</td>
</tr>
<tr>
<td>Types of distress</td>
<td>The subclassification of the various manifestations of a particular mode of distress</td>
</tr>
<tr>
<td>Wearing</td>
<td>Type of distress of the mode &quot;loss of surface texture depth&quot;</td>
</tr>
</tbody>
</table>
BIBLIOGRAPHY


FIGURE 1

THE PERFORMANCE OF A HYPOTHETICAL ROAD

FIGURE 2

ILLUSTRATION OF THE SLOPE OF THE ROAD AT A POINT, DEFINED FOR THE PURPOSE OF CALCULATING THE SLOPE VARIANCE
FIGURE 3. The CHLOE profilometer.
FIGURE 4. The PCA roadmeter

FIGURE 5. The BPR roughometer
FIGURE 8. The pendulum tester.
FIGURE 9
A section of road with poor surface drainage
FIGURE 10

COMPONENTS OF THE PAVEMENT STRUCTURE
(a) THE MEASUREMENT OF A DEPRESSION

(b) THE MEASUREMENT OF A MOUND

FIGURE 11
THE METHOD OF MEASURING THE DEGREE OF DEFORMATION
FIGURE 12

Distress: Depression, Degree 5 in outer wheel path
Cause: Low grade base material and poor subsurface drainage
Mechanism: Plastic flow (shear) of base material.

FIGURE 13

Distress: Depression on edge of pavement (causing ponding of water)
Cause: Poor surface drainage
Mechanism: Compaction of subgrade
FIGURE 14

Distress : Rut in outer wheel path, Degree 5
Cause : Poor subsurface drainage
Mechanism : Compaction of pavement

FIGURE 15

Distress : Transverse ridge
Cause : Active clay subgrade
Mechanism : Differential heaving of subgrade under culvert because of lesser weight of culvert
FIGURE 16.

Distress: Corrugations, Degree 3 Length 5 Sp. 1 m.
Cause: Unstable base material and tangential forces of traffic due to down grade of road.
Mechanism: Shoving

FIGURE 17

Distress: Distortion
Cause: Active subgrade
Mechanism: Heave
FIGURE 18

Distress: Transverse crack, Degree 4

FIGURE 19.

Distress: Transverse crack, Degree 5.
FIGURE 20

**distress** : Transverse cracks, Degree 5 Spa. 1.8 m.
**Cause** : Shrinkage of natural gravel base.
**Mechanism** : Reflection of cracks through surfacing.

FIGURE 21

**Distress** : Longitudinal crack, Degree 5.
**Cause** : Poor construction joint in premix surfacing.
**Mechanism** : Fatigue.
FIGURE 22
Distress : Block cracks, Degree Spa. 1 m
Cause : Ageing of binder
Mechanism : Shrinkage of binder

FIGURE 23
Distress : Block cracks, Degree 5 Spa. 3 m
Cause : Shrinkage and cracking of stabilised base
Mechanism : Reflection of cracks through surface
FIGURE 24

Distress : Crocodile cracks, Degree 2
(Straight edge marked horizontally in decimeters)

FIGURE 25.

Distress : Crocodile cracks, Degree 3.
FIGURE 26

Distress : Crocodile cracks, Degree 4.

FIGURE 27

Distress : Crocodile cracks, Degree 5.
FIGURE 28

Distress: Parabolic cracks, Degree 5
Cause: Poor bond between surfacing and base on steep upgrade
Mechanism: Shear at the interface of the base and surfacing
FIGURE 29. The result of pumping through crocodile cracks (degree 2) (The rule in the figure is calibrated in centimetres)
Figure 30

Distress: Longitudinal cracks with secondary development of ladder cracks
Cause: Binder hardening and low structural support
Mechanism: Fatigue of surfacing

Figure 31

Distress: Multiple cracks, Degree 5
Primary transverse cracking, Secondary block cracking followed by crocodile cracking
Cause: Hard (brittle) binder in surfacing
Mechanism: Shrinkage of surfacing
FIGURE 32

Distress: Loss of stone, Degree 1
(good surfacing with intact matrix)

FIGURE 33.
General view of the surfacing in Figure 32.
FIGURE 34
Distress : Loss of stone, Degree 5 Spa. 10 mm
Cause   : Quartzite aggregate contaminated by shale
Mechanism : Fracture

FIGURE 35
Distress : Loss of stone, Degree 5 Spa. 50 mm
Cause   : Ageing of the binder
Mechanism : Ravelling
FIGURE 36

Distress : Loss of stone, Degree 5 Spa. 100 mm
Cause : Ageing of binder
Mechanism : Ravelling

FIGURE 37

Distress : Loss of stone, Degree 5 Area 5 Spa. > 100 mm
Cause : Too hard a grade of binder used
Mechanism : Loss of adhesion
FIGURE 38
Distress: Pothole, Degree 5
Cause: Crocodile cracking of surfacing
Mechanism: Spalling

FIGURE 39
Distress: Edge break, Degree 4.
Cause: Salt action caused loss of aggregate on shoulder and thus weak support for premix
Mechanism: Shearing off of premix at edge of pavement
FIGURE 40

Distress : Fatting, Degree 4
Cause : Surfacing mix too rich
Mechanism : Reorientation of stones under traffic

FIGURE 41

General view of the road in Figure 40.
**FIGURE 42**

Distress : Polishing, Degree 1  
(stones are harsh, sharp and angular)

**FIGURE 43**

Distress : Polishing, Degree 5  
Cause : Stone has low polish stone value (PSV)